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# Oblique Shock and Expansion Waves Formulas

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# List of 20 Oblique Shock and Expansion Waves Formulas

## Oblique Shock and Expansion Waves

### Expansion Waves

#### 1) Flow Deflection Angle due to Expansion Wave

Open Calculator

fx
$$\theta_e = \left( \sqrt{\frac{\gamma_e + 1}{\gamma_e - 1}} \cdot a\tan\left( \sqrt{\frac{(\gamma_e - 1) \cdot (M_{e2}^2 - 1)}{\gamma_e + 1}} \right) - a\tan\left( \sqrt{M_{e2}^2 - 1} \right) \right) - \left( \sqrt{\frac{\gamma_e + 1}{\gamma_e - 1}} \cdot \right.$$

ex
$$7.866893^\circ = \left( \sqrt{\frac{1.41 + 1}{1.41 - 1}} \cdot a\tan\left( \sqrt{\frac{(1.41 - 1) \cdot \left( (6)^2 - 1 \right)}{1.41 + 1}} \right) - a\tan\left( \sqrt{(6)^2 - 1} \right) \right) - \left( \sqrt{\frac{1.41 + 1}{1.41 - 1}} \cdot a \right.$$

#### 2) Flow Deflection Angle using Prandtl Meyer Function

Open Calculator

fx $\theta_e = v_{M2} - v_{M1}$

ex $6^\circ = 83^\circ - 77^\circ$

#### 3) Forward Mach Angle of Expansion Fan

Open Calculator

fx $\mu_1 = ar\sin\left( \frac{1}{M_{e1}} \right)$

ex $11.53696^\circ = ar\sin\left( \frac{1}{5} \right)$

#### 4) Prandtl Meyer Function

Open Calculator

fx
$$v_M = \sqrt{\frac{\gamma_e + 1}{\gamma_e - 1}} \cdot a\tan\left( \sqrt{\frac{(\gamma_e - 1) \cdot (M^2 - 1)}{\gamma_e + 1}} \right) - a\tan\left( \sqrt{M^2 - 1} \right)$$

ex
$$94.20208^\circ = \sqrt{\frac{1.41 + 1}{1.41 - 1}} \cdot a\tan\left( \sqrt{\frac{(1.41 - 1) \cdot \left( (8)^2 - 1 \right)}{1.41 + 1}} \right) - a\tan\left( \sqrt{(8)^2 - 1} \right)$$

## 5) Prandtl Meyer Function at Upstream Mach Number

Open Calculator

fx $$v_{M1} = \sqrt{\frac{\gamma_e + 1}{\gamma_e - 1}} \cdot a\tan\left(\sqrt{\frac{(\gamma_e - 1) \cdot (M_{e1}^2 - 1)}{\gamma_e + 1}}\right) - a\tan\left(\sqrt{M_{e1}^2 - 1}\right)$$

ex $$75.90175° = \sqrt{\frac{1.41 + 1}{1.41 - 1}} \cdot a\tan\left(\sqrt{\frac{(1.41 - 1) \cdot \left((5)^2 - 1\right)}{1.41 + 1}}\right) - a\tan\left(\sqrt{(5)^2 - 1}\right)$$

## 6) Pressure behind Expansion Fan

Open Calculator

fx $$P_2 = P_1 \cdot \left(\frac{1 + 0.5 \cdot (\gamma_e - 1) \cdot M_{e1}^2}{1 + 0.5 \cdot (\gamma_e - 1) \cdot M_{e2}^2}\right)^{\frac{\gamma_e}{\gamma_e - 1}}$$

ex $$13.61063\text{Pa} = 40\text{Pa} \cdot \left(\frac{1 + 0.5 \cdot (1.41 - 1) \cdot (5)^2}{1 + 0.5 \cdot (1.41 - 1) \cdot (6)^2}\right)^{\frac{1.41}{1.41 - 1}}$$

## 7) Pressure Ratio across Expansion Fan

Open Calculator

fx $$P_{e,r} = \left(\frac{1 + 0.5 \cdot (\gamma_e - 1) \cdot M_{e1}^2}{1 + 0.5 \cdot (\gamma_e - 1) \cdot M_{e2}^2}\right)^{\frac{\gamma_e}{\gamma_e - 1}}$$

ex $$0.340266 = \left(\frac{1 + 0.5 \cdot (1.41 - 1) \cdot (5)^2}{1 + 0.5 \cdot (1.41 - 1) \cdot (6)^2}\right)^{\frac{1.41}{1.41 - 1}}$$

## 8) Rearward Mach Angle of Expansion Fan

Open Calculator

fx $$\mu_2 = ar\sin\left(\frac{1}{M_{e2}}\right)$$

ex $$9.594068° = ar\sin\left(\frac{1}{6}\right)$$

## 9) Temperature behind Expansion Fan

Open Calculator

fx $$T_2 = T_1 \cdot \left(\frac{1 + 0.5 \cdot (\gamma_e - 1) \cdot M_{e1}^2}{1 + 0.5 \cdot (\gamma_e - 1) \cdot M_{e2}^2}\right)$$

ex $$288.065\text{K} = 394.12\text{K} \cdot \left(\frac{1 + 0.5 \cdot (1.41 - 1) \cdot (5)^2}{1 + 0.5 \cdot (1.41 - 1) \cdot (6)^2}\right)$$

### 10) Temperature Ratio across Expansion Fan

Open Calculator

fx $$T_{e,r} = \frac{1 + 0.5 \cdot (\gamma_e - 1) \cdot M_{e1}^2}{1 + 0.5 \cdot (\gamma_e - 1) \cdot M_{e2}^2}$$

ex $$0.730907 = \frac{1 + 0.5 \cdot (1.41 - 1) \cdot (5)^2}{1 + 0.5 \cdot (1.41 - 1) \cdot (6)^2}$$

## Oblique Shock

### 11) Component of Downstream Mach Normal to Oblique Shock

Open Calculator

fx $$M_{n2} = M_2 \cdot \sin(\beta - \theta)$$

ex $$0.666082 = 1.21 \cdot \sin(53.4^\circ - 20^\circ)$$

### 12) Component of Downstream Mach Number Normal to Oblique Shock for given Normal Upstream Mach Number

Open Calculator

fx $$M_{n2} = \sqrt{\frac{1 + 0.5 \cdot (\gamma_o - 1) \cdot M_{n1}^2}{\gamma_o \cdot M_{n1}^2 - 0.5 \cdot (\gamma_o - 1)}}$$

ex $$0.66664 = \sqrt{\frac{1 + 0.5 \cdot (1.4 - 1) \cdot (1.606)^2}{1.4 \cdot (1.606)^2 - 0.5 \cdot (1.4 - 1)}}$$

### 13) Component of Upstream Mach Normal to Oblique Shock

Open Calculator

fx $$M_{n1} = M_1 \cdot \sin(\beta)$$

ex $$1.605635 = 2 \cdot \sin(53.4^\circ)$$

### 14) Density behind Oblique Shock for given Upstream Density and Normal Upstream Mach Number

Open Calculator

fx $$\rho_2 = \rho_1 \cdot \left( (\gamma_o + 1) \cdot \frac{M_{n1}^2}{2 + (\gamma_o - 1) \cdot M_{n1}^2} \right)$$

ex $$2.501226\text{kg/m}^3 = 1.225\text{kg/m}^3 \cdot \left( (1.4 + 1) \cdot \frac{(1.606)^2}{2 + (1.4 - 1) \cdot (1.606)^2} \right)$$

## 15) Density Ratio across Oblique Shock

Open Calculator

fx $$\rho_r = (\gamma_o + 1) \cdot \frac{M_{n1}^2}{2 + (\gamma_o - 1) \cdot M_{n1}^2}$$

ex $$2.041817 = (1.4 + 1) \cdot \frac{(1.606)^2}{2 + (1.4 - 1) \cdot (1.606)^2}$$

## 16) Flow Deflection Angle due to Oblique Shock

Open Calculator

fx $$\theta = a\tan\left(\frac{2 \cdot \cot(\beta) \cdot \left((M_1 \cdot \sin(\beta))^2 - 1\right)}{M_1^2 \cdot (\gamma_o + \cos(2 \cdot \beta)) + 2}\right)$$

ex $$19.98876^\circ = a\tan\left(\frac{2 \cdot \cot(53.4^\circ) \cdot \left((2 \cdot \sin(53.4^\circ))^2 - 1\right)}{(2)^2 \cdot (1.4 + \cos(2 \cdot 53.4^\circ)) + 2}\right)$$

## 17) Pressure behind Oblique Shock for given Upstream Pressure and Normal Upstream Mach Number

Open Calculator

fx $$P_b = P_a \cdot \left(1 + \left(\frac{2 \cdot \gamma_o}{\gamma_o + 1}\right) \cdot (M_{n1}^2 - 1)\right)$$

ex $$166.2829\text{Pa} = 58.5\text{Pa} \cdot \left(1 + \left(\frac{2 \cdot 1.4}{1.4 + 1}\right) \cdot \left((1.606)^2 - 1\right)\right)$$

## 18) Pressure Ratio across Oblique Shock

Open Calculator

fx $$P_r = 1 + \left(\frac{2 \cdot \gamma_o}{\gamma_o + 1}\right) \cdot (M_{n1}^2 - 1)$$

ex $$2.842442 = 1 + \left(\frac{2 \cdot 1.4}{1.4 + 1}\right) \cdot \left((1.606)^2 - 1\right)$$

## 19) Temperature behind Oblique Shock for given Upstream Temperature and Normal Upstream Mach Number

Open Calculator

fx $$T_{s2} = T_{s1} \cdot \left(\frac{1 + \left(\frac{2 \cdot \gamma_o}{\gamma_o + 1}\right) \cdot (M_{n1}^2 - 1)}{(\gamma_o + 1) \cdot \frac{M_{n1}^2}{2 + (\gamma_o - 1) \cdot M_{n1}^2}}\right)$$

ex $$400.9287\text{K} = 288\text{K} \cdot \left(\frac{1 + \left(\frac{2 \cdot 1.4}{1.4 + 1}\right) \cdot \left((1.606)^2 - 1\right)}{(1.4 + 1) \cdot \frac{(1.606)^2}{2 + (1.4 - 1) \cdot (1.606)^2}}\right)$$

## 20) Temperature Ratio across Oblique Shock

Open Calculator

fx $$T_r = \frac{1 + \left(\frac{2 \cdot \gamma_o}{\gamma_o + 1}\right) \cdot \left(M_{n1}^2 - 1\right)}{\left(\gamma_o + 1\right) \cdot \frac{M_{n1}^2}{2 + (\gamma_o - 1) \cdot M_{n1}^2}}$$

ex $$1.392114 = \frac{1 + \left(\frac{2 \cdot 1.4}{1.4 + 1}\right) \cdot \left((1.606)^2 - 1\right)}{(1.4 + 1) \cdot \frac{(1.606)^2}{2 + (1.4 - 1) \cdot (1.606)^2}}$$

## Variables Used

- **$M$** Mach Number
- **$M_1$** Mach Number Ahead of Oblique Shock
- **$M_2$** Mach Number Behind Oblique Shock
- **$M_{e1}$** Mach Number Ahead of Expansion Fan
- **$M_{e2}$** Mach Number Behind Expansion Fan
- **$M_{n1}$** Upstream Mach Normal to Oblique Shock
- **$M_{n2}$** Downstream Mach Normal to Oblique Shock
- **$P_1$** Pressure Ahead of Expansion Fan *(Pascal)*
- **$P_2$** Pressure Behind Expansion Fan *(Pascal)*
- **$P_a$** Static Pressure Ahead of Oblique Shock *(Pascal)*
- **$P_b$** Static Pressure Behind Oblique Shock *(Pascal)*
- **$P_{e,r}$** Pressure Ratio Across Expansion Fan
- **$P_r$** Pressure Ratio Across Oblique Shock
- **$T_1$** Temperature Ahead of Expansion Fan *(Kelvin)*
- **$T_2$** Temperature Behind Expansion Fan *(Kelvin)*
- **$T_{e,r}$** Temperature Ratio Across Expansion Fan
- **$T_r$** Temperature Ratio Across Oblique Shock
- **$T_{s1}$** Temperature Ahead of Oblique Shock *(Kelvin)*
- **$T_{s2}$** Temperature Behind Oblique Shock *(Kelvin)*
- **$v_{M1}$** Prandtl Meyer Function at Upstream Mach no. *(Degree)*
- **$v_{M2}$** Prandtl Meyer Function at Downstream Mach no. *(Degree)*
- **$\beta$** Oblique Shock Angle *(Degree)*
- **$\gamma_e$** Specific Heat Ratio Expansion Wave
- **$\gamma_o$** Specific Heat Ratio Oblique Shock
- **$\theta$** Flow Deflection Angle Oblique Shock *(Degree)*
- **$\theta_e$** Flow Deflection Angle *(Degree)*
- **$\mu_1$** Forward Mach Angle *(Degree)*
- **$\mu_2$** Rearward Mach Angle *(Degree)*
- **$v_M$** Prandtl Meyer Function *(Degree)*
- **$\rho_1$** Density Ahead of Oblique Shock *(Kilogram per Cubic Meter)*
- **$\rho_2$** Density Behind Oblique Shock *(Kilogram per Cubic Meter)*
- **$\rho_r$** Density Ratio Across Oblique Shock

## Constants, Functions, Measurements used

- Function: **arsin**, arsin(Number)
  *Arcsine function, is a trigonometric function that takes a ratio of two sides of a right triangle and outputs the angle opposite the side with the given ratio.*
- Function: **atan**, atan(Number)
  *Inverse tan is used to calculate the angle by applying the tangent ratio of the angle, which is the opposite side divided by the adjacent side of the right triangle.*
- Function: **cos**, cos(Angle)
  *Cosine of an angle is the ratio of the side adjacent to the angle to the hypotenuse of the triangle.*
- Function: **cot**, cot(Angle)
  *Cotangent is a trigonometric function that is defined as the ratio of the adjacent side to the opposite side in a right triangle.*
- Function: **sin**, sin(Angle)
  *Sine is a trigonometric function that describes the ratio of the length of the opposite side of a right triangle to the length of the hypotenuse.*
- Function: **sqrt**, sqrt(Number)
  *A square root function is a function that takes a non-negative number as an input and returns the square root of the given input number.*
- Function: **tan**, tan(Angle)
  *The tangent of an angle is a trigonometric ratio of the length of the side opposite an angle to the length of the side adjacent to an angle in a right triangle.*
- Measurement: **Temperature** in Kelvin (K)
  *Temperature Unit Conversion*
- Measurement: **Pressure** in Pascal (Pa)
  *Pressure Unit Conversion*
- Measurement: **Angle** in Degree (°)
  *Angle Unit Conversion*
- Measurement: **Density** in Kilogram per Cubic Meter (kg/m³)
  *Density Unit Conversion*

## Check other formula lists

- **Governing Equations and Sound Wave Formulas**
- **Oblique Shock and Expansion Waves Formulas**
- **Normal Shock Wave Formulas**

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